STUDY ON MECHANICAL BEHAVIOR OF COIR FIBER REINFORCED POLYMER MATRIX COMPOSITES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Bachelor of Technology in Mechanical Engineering

BY

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DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
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CERTIFICATE

This is to certify that the thesis entitled "***Study on Mechanical Behavior of Coir Fiber Reinforced Polymer Matrix Composites***" submitted by **Sanjay Kindo (Roll Number: 10603053)** in partial fulfillment of the requirements for the award of ***Bachelor of Technology*** in the department of Mechanical Engineering, National Institute of Technology, Rourkela is an authentic work carried out under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to elsewhere for the award of any degree.

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A C K N O W L E D G E M E N T

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A B S T R A C T

Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The fiber which serves as a reinforcement in reinforced plastics may be synthetic or natural. Past studies show that only synthetic fibers such as glass, carbon etc., have been used in fiber-reinforced plastics. Although glass and other synthetic fiber-reinforced plastics possess high specific strength, their fields of application are very limited because of their inherent higher cost of production. In this connection, an investigation has been carried out to make use of coir, a natural fiber abundantly available in India. Natural fibers are not only strong and lightweight but also relatively very cheap. The present work describes the development and characterization of a new set of natural fiber based polymer composites consisting of coconut coir as reinforcement and epoxy resin. The newly developed composites are characterized with respect to their mechanical characteristics. Experiments are carried out to study the effect of fiber length on mechanical behavior of these epoxy based polymer composites. In the present work, coir composites are developed and their mechanical properties are evaluated. Scanning electron micrographs obtained from fractured surfaces were used for a qualitative evaluation of the interfacial properties of coir/epoxy. These results indicate that coir can be used as a potential reinforcing material for many structural and non-structural applications. This work can be further extended to study other aspects of such composites like effect of fiber content, fiber orientation, loading pattern, fiber treatment on mechanical behavior of coconut coir based polymer composites.

Finally, the SEM of fractured surfaces has been done to study their surface morphology.

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Chapter 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1. Overview of composites

The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. By definition, composite materials consist of two or more constituents with physically separable phases [1, 2]. However, only when the composite phase materials have notably different physical properties it is recognized as being a composite material. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties; yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material. Long fibers that are oriented in the direction of loading offer the most efficient load transfer. This is because the stress transfer zone extends only over a small part of the fiber-matrix interface and perturbation effects at fiber ends may be neglected. In other words, the ineffective fiber length is small. Popular fibers available as continuous filaments for use in high performance composites are glass, carbon and aramid fibers.

1.2. Types of Composites

For the sake of simplicity, however, composites can be grouped into categories based on the nature of the matrix each type possesses [3]. Methods of fabrication also vary according to physical and chemical properties of the matrices and reinforcing fibers.

(a) Metal Matrix Composites (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

(b) Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumino silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumino silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cement and concreted carbon components.

(c) Polymer Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

1.3. Natural Fiber Composites

Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The manufacture, use and removal of traditional fiber–reinforced plastic, usually made of glass, carbon or aramid fibers–reinforced thermoplastic and thermoset resins are considered critically because of environmental problems. By natural fiber composites we mean a composite material that is reinforced with fibers, particles or platelets from natural or renewable resources, in contrast to for example carbon or aramide fibers that have to be synthesized. Natural fibers include those made from plant, animal and mineral sources. Natural fibers can be classified according to their origin. The detailed classification is shown in Figure 1.1.

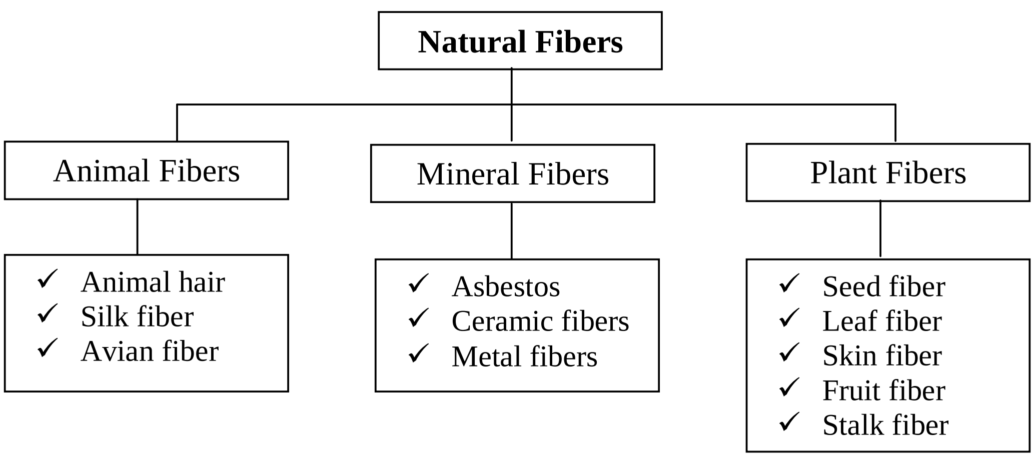

Figure 1.1 Classification of natural fibers

Animal Fiber: Animal fiber generally comprise proteins; examples mohair, wool, silk, alpaca, angora. Animal hair (wool or hair) are the fibers taken from animals or hairy mammals. E.g. Sheep's wool, goat hair (cashmere, mohair), alpaca hair, horse hair, etc. Silk fiber are the fibers collected from dried saliva of bugs or insects during the preparation of cocoons. Examples include silk from silk worms. Avian fiber are the fibers from birds, e.g. feathers and feather fiber.

Mineral fiber: Mineral fibers are naturally occurring fiber or slightly modified fiber procured from minerals. These can be categorized into the following categories: Asbestos is the only naturally occurring mineral fiber. Varietions are serpentine and amphiboles, anthophyllite. Ceramic fibers includes glass fibers (Glass wood and Quartz), aluminium oxide, silicon carbide, and boron carbide. Metal fibers includes aluminium fibers

Plant fiber: Plant fibers are generally comprised mainly of cellulose: examples include cotton, jute, flax, ramie, sisal and hemp. Cellulose fibers serve in the manufacture of paper and cloth. This fiber can be further categorizes into following as : Seed fiber are the fibers collected from the seed and seed case e.g. cotton and kapok. Leaf fibe are the fibers collected from the leaves e.g. sisal and agave. Skin fiber are the fibers are collected from the skin or bast surrounding the stem of their respective plant. These fibers have higher tensile strength than other fibers. Therefore, these fibers are used for durable yarn, fabric, packaging, and paper. Some examples are flax, jute, banana, hemp, and soybean. Fruit fiber are the fibers are collected from the fruit of the plant, e.g. coconut (coir) fiber. Stalk fiber are the fibers are actually the stalks of the plant. E.g. straws of wheat, rice, barley, and other crops including bamboo and grass. Tree wood is also such a fiber.

Natural fiber composites are by no means new to mankind. Already the ancient Egyptians used clay that was reinforced by straw to build walls. In the beginning of the 20th century wood- or cotton fiber reinforced phenol- or melamine formaldehyde resins were fabricated and used in electrical applications for their non-conductive and heat-resistant properties. At present day natural fiber composites are mainly found in automotive and building industry and then mostly in applications where load bearing capacity and dimensional stability under moist and high thermal conditions are of second order importance. For example, flax fiber reinforced polyolefins are extensively used today in the automotive industry, but the fiber acts mainly as filler material in non-structural interior panels [4]. Natural fiber composites used for structural purposes do exist, but then usually with synthetic thermoset matrices which of course limit the environmental benefits [5, 6]. The natural fiber composites can be very cost effective material for following applications:

- Building and construction industry: panels for partition and false ceiling, partition boards, wall, floor, window and door frames, roof tiles, mobile or pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc.
- Storage devices: post-boxes, grain storage silos, bio-gas containers, etc.
- Furniture: chair, table, shower, bath units, etc.
- Electric devices: electrical appliances, pipes, etc.
- Everyday applications: lampshades, suitcases, helmets, etc.
- Transportation: automobile and railway coach interior, boat, etc.

Natural fibers are generally lignocellulosic in nature, consisting of helically wound cellulose micro fibrils in a matrix of lignin and hemicellulose. According to a Food and Agricultural Organization survey, Tanzania and Brazil produce the largest amount of sisal. Henequen is grown in Mexico. Abaca and hemp are grown in the Philippines. The largest producers of jute are India, China, and Bangladesh. Presently, the annual production of natural fibers in India is about 6 million tons as compared to worldwide production of about 25 million tons. The detail information of fibers and the countries of origin are given in Table 1.1.

Table.1.1 Fibers and countries of origin [7]

Flax	Borneo
Hemp	Yugoslavia, china
Sun Hemp	Nigeria, Guyana, Siera Leone, India
Ramie	Hondurus, Mauritius
Jute	India, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan, Tanzania
Kenaf	Iraq, Tanzania, Jamaica, South Africa, Cuba, Togo
Roselle	Borneo, Guyana, Malaysia, Sri Lanka, Togo, Indonesia, Tanzania
Sisal	East Africa, Bahamas, Antiqua, Kenya, Tanzania, India
Abaca	Malaysia, Uganda, Philippines, Bolivia
Coir	India, Sri Lanka, Philippines, Malaysia

Natural fibres such as jute, sisal, pineapple, abaca and coir [8–17] have been studied as a reinforcement and filler in composites. Growing attention is nowadays being paid to coconut fiber due to its availability. The coconut husk is available in large quantities as residue from coconut production in many areas, which is yielding the coarse coir fiber. Coir is a lingo-cellulosic natural fiber. It is a seed-hair fiber obtained from the outer shell, or husk, of the coconut. It is resistant to abrasion and can be dyed. Total world coir fiber production is 250,000 tonnes. The coir fiber industry is particularly important in some areas of the developing world. Over 50% of the coir fiber produced annually throughout the world is consumed in the countries of origin, mainly India [18]. Because of its hard-wearing quality, durability and other advantages, it is used for making a wide variety of floor furnishing materials, yarn, rope etc [19]. However, these traditional coir products consume only a small percentage of the potential total world production of coconut husk. Hence, research and development efforts have been underway to find new use areas for coir, including utilization of coir as reinforcement in polymer composites [20-26].

Although there are several reports in the literature which discuss the mechanical behavior of natural fiber reinforced polymer composites. However, very limited work has been done on effect of fiber length on mechanical behaviour of coir fiber reinforced epoxy composites. Against this background, the present research work has been undertaken, with an objective to explore the potential of coir fiber as a reinforcing material in polymer composites and to investigate its effect on the mechanical behaviour of the resulting composites. The present work thus aims to develop this new class of natural fibre based polymer composites with different fiber lengths and to analyse their mechanical behaviour by experimentation.

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Chapter 2

LITERATURE SURVEY

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LITERATURE SURVEY

This chapter outlines some of the recent reports published in literature on mechanical behaviour of natural fiber based polymer composites with special emphasis on coir fiber reinforced polymer composites.

(i) On natural fiber reinforced composites

The mechanical properties of a natural fiber-reinforced composite depend on many parameters, such as fiber strength, modulus, fiber length and orientation, in addition to the fiber-matrix interfacial bond strength. A strong fiber-matrix interface bond is critical for high mechanical properties of composites. A good interfacial bond is required for effective stress transfer from the matrix to the fiber whereby maximum utilization of the fiber strength in the composite is achieved [27]. Modification to the fiber also improves resistance to moisture-induced degradation of the interface and the composite properties [28]. In addition, factors like processing conditions/techniques have significant influence on the mechanical properties of fiber reinforced composites [29]. Mechanical properties of natural fibers, especially flax, hemp, jute and sisal, are very good and may compete with glass fiber in specific strength and modulus [30, 31]. A number of investigations have been conducted on several types of natural fibers such as kenaf, hemp, flax, bamboo, and jute to study the effect of these fibers on the mechanical properties of composite materials [32-35]. Mansur and Aziz [34] studied bamboo-mesh reinforced cement composites, and found that this reinforcing material could enhance the ductility and toughness of the cement matrix, and increase significantly its tensile, flexural, and impact strengths. On the other hand, jute fabric-reinforced polyester composites were tested for the evaluation of mechanical properties and compared with wood composite [35], and it was found that the jute fiber composite has better strengths than wood composites. A pulp fiber reinforced thermoplastic composite was investigated and found to have a combination of stiffness increased by a factor of 5.2 and strength increased by a factor of 2.3 relative to the virgin polymer [36]. Information on the usage of banana fibers in reinforcing polymers is limited in the literature. In dynamic mechanical analysis, Laly *et al*. [37] have investigated banana fiber reinforced polyester composites and found that the optimum content of banana fiber is 40%. Mechanical properties of banana–fiber–cement composites were investigated physically and mechanically by Corbiere-Nicollier *et al*. [38]. It was reported that kraft pulped banana fiber composite has good flexural strength. In addition, short banana fiber reinforced polyester composite was studied by Pothan *et al*. [39]; the study concentrated on the effect of fiber length and fiber content. The maximum tensile strength was observed at 30 mm fiber length while maximum impact strength was observed at 40 mm fiber length. Incorporation of 40% untreated fibers provides a 20% increase in the tensile strength and a 34% increase in impact strength. Joseph *et al*. [40] tested banana fiber and glass fiber with varying fiber length and fiber content as well. Luo and Netravali [41] studied the tensile and flexural properties of the green composites with different pineapple fibre content and compared with the virgin resin. Sisal fibre is fairly coarse and inflexible. It has good strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in seawater. Sisal ropes and twines are widely used for marine, agricultural, shipping, and general industrial use. Belmeres et al. [42] found that sisal, henequen, and palm fibre have very similar physical, chemical, and tensile properties. Cazaurang et al. [43] carried out a systematic study on the properties of henequen fibre and pointed out that these fibres have mechanical properties suitable for reinforcing thermoplastic resins. Ahmed et al.[44] carried out research work on filament wound cotton fibre reinforced for reinforcing high-density polyethylene (HDPE) resin. Khalid et al. [45] also studied the use of cotton fibre reinforced epoxy composites along with glass fibre reinforced polymers. Fuad et al. [46] investigated the new type woodbased filler derived from oil palm wood flour (OPWF) for bio-based thermoplastics composites by thermo gravimetric analysis and the results are very promising. Schneider and Karmaker [47] developed composites using jute and kenaf fibre and polypropylene resins and they reported that jute fibre provides better mechanical properties than kenaf fibre. Sreekala et al. [48] performed one of the pioneering studies on the mechanical performance of treated oil palm fiber-reinforced composites. They studied the tensile stress-stain behavior of composites having 40% by weight fiber loading. Isocyananante-, silane-, acrylated, latex coated and peroxide-treated composite withstood tensile stress to higher strain level. Isocyanate treated, silane treated, acrylated, acetylated and latex coated composites showed yielding and high extensibility. Tensile modulus of the composites at 2% elongation showed slight enhancement upon mercerization and permanganate treatment. The elongation at break of the composites with chemically modified fiber was attributed to the changes in the chemical structure and bondability of the fiber. Alkali treated (5%) sisal-polyester biocomposite showed about 22% increase in tensile strength [49]. Ichazo et al. [50] found that adding silane treated wood flour to PP produced a sustained increase in the tensile modulus and tensile strength of the composite. Joseph and Thomas [51] studied the effect of chemical treatment on the tensile and dynamic mechanical properties of short sisal fiberreinforced low density polyethylene composites. It was observed that the CTDIC (cardanol derivative of toluene diisocyanate) treatment reduced the hydrophilic nature of the sisal fiber and enhanced the tensile properties of the sisal-LDPE composites. They found that peroxide and permanganate treated fiber-reinforced composites showed an enhancement in tensile properties. They concluded that with a suitable fiber surface treatment, the mechanical properties and dimensional stability of sisal-LDPE composites could be improved. Mohanty et al. [52] studied the influence of different surface modifications of jute on the performance of the biocomposites. More than a 40% improvement in the tensile strength occurred as a result of reinforcement with alkali treated jute. Jute fiber content also affected the biocomposite performance and about 30% by weight of jute showed optimum properties of the biocomposites.

(ii) On coir fiber reinforced composites

Many aspects of the use of coir fibers as reinforcement in polymer–matrix composites are described in the literature. Coir is an abundant, versatile, renewable, cheap, and biodegradable lignocellulosic fiber used for making a wide variety of products [53]. Coir has also been tested as a filler or a reinforcement in different composite materials [54-57]. Furthermore, it represents an additional agro-industrial nonfood feedstock (agro industrial and food industry waste) that should be considered as feedstock for the formulation of ecocompatible composite materials. Coconut coir is the most interesting products as it has the lowest thermal conductivity and bulk density. The addition of coconut coir reduced the thermal conductivity of the composite specimens and yielded a lightweight product. Development of composite materials for buildings using natural fiber as coconut coir with low thermal conductivity is an interesting alternative which would solve environment and energy concern [58, 59]. Geethamma et al. [60] have studied the dynamic mechanical behavior of natural rubber and its composites reinforced with short coir fibers.

Coir fiber–polyester composites were tested as helmets, as roofing and post-boxes [61]. These composites, with coir loading ranging from 9 to 15 wt%, have a flexural strength of about 38 MPa. Coir–polyester composites with untreated and treated coir fibers, and with fiber loading of 17 wt%, were tested in tension, flexure and notched Izod impact [62]. The results obtained with the untreated fibers show clear signs of the presence of a weak interface long pulled-out fibers without any resin adhered to the fibers—and low mechanical properties were obtained. Although showing better mechanical performance, the composites with treated fibers present, however, only a moderate increase on the values of the mechanical properties analyzed. Alkali treatment is also reported for coir fibers [63, 64]. Treated fiber–polyester composites, with volume fraction ranging from 10% to 30%, show better properties than composites with untreated fibers, but the flexural strength of these composites was consistently lower than that of the bare matrix. A maximum value of 42.3MPa is reported against a value of 48.5MPa for the neat polyester. Acetylation of coir fibers increases the hydrophobic behaviour, increases the resistance to fungi attack and also increases the tensile strength of coir–polyester composites [65, 66]. However, the fiber loading has to be fairly high, 45 wt% or even higher, to attain a significant reinforcing effect when the composite is tested in tension. Moreover, even with high coir fiber loading fractions, there is no improvement in the flexural strength [66]. From these results, it is apparent that the usual fiber treatments reported so far did not significantly change the mechanical performance of coir–polyester composites.

Although there are several reports in the literature which discuss the mechanical behavior of natural fiber reinforced polymer composites. However, very limited work has been done on effect of fiber length on mechanical behaviour of coir fiber reinforced epoxy composites. Against this background, the present research work has been undertaken, with an objective to explore the potential of coir fiber as a reinforcing material in polymer composites and to investigate its effect on the mechanical behaviour of the resulting composites. The present work thus aims to develop this new class of natural fibre based polymer composites with different fiber lengths and to analyse their mechanical behaviour by experimentation.

2.1 Objectives of the Research Work

The objectives of the project are outlined below.

- To develop a new class of natural fiber based polymer composites to explore the potential of coir fiber.
- To study the effect of fiber length on mechanical behaviour of coir fiber reinforced epoxy based composites.

- Evaluation of mechanical properties such as: tensile strength, flexural strength, tensile modulus, micro-hardness, impact strength etc.

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Chapter 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

This chapter describes the details of processing of the composites and the experimental procedures followed for their mechanical characterization. The raw materials used in this work are

1. Coconut coir fiber
2. Epoxy resin
3. Hardener

3.1. Specimen preparation

The fabrication of the various composite materials is carried out through the hand lay-up technique. Short coconut coir fibers (Figure 3. 1) are reinforced with Epoxy LY 556 resin, chemically belonging to the ‘epoxide’ family is used as the matrix material. Its common name is Bisphenol A Diglycidyl Ether. The low temperature curing epoxy resin (Araldite LY 556) and corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as recommended. The epoxy resin and the hardener are supplied by Ciba Geigy India Ltd. The coir fiber is collected from rural areas of Orissa, India. Three different types of composites has been fabricated with three different fiber lengths such as 5mm, 20mm and 30mm. Each composite consisting of 30% of fiber and 70% of epoxy resin. The designations of these composites are given in Table 3.1. The mix is stirred manually to disperse the fibers in the matrix. The cast of each composite is cured under a load of about 50 kg for 24 hours before it removed from the mould. Then this cast is post cured in the air for another 24 hours after removing out of the mould. Specimens of suitable dimension are cut using a diamond cutter for mechanical testing. Utmost care has been taken to maintain uniformity and homogeneity of the composite.

Figure 3.1 Coconut coir fiber

Table 3.1 Designation of Composites

Composites	Compositions
C_1	Epoxy (70wt%)+Coir Fiber (fiber length 5mm) (30wt%)
C_2	Epoxy (70wt%)+Coir Fiber (fiber length 20mm) (30wt%)
C_3	Epoxy (70wt%)+Coir Fiber (fiber length 30mm) (30wt%)

3.2. Mechanical Testing

After fabrication the test specimens were subjected to various mechanical tests as per ASTM standards. The tensile test and three-point flexural tests of composites were carried out using Instron 1195. The tensile test is generally performed on flat specimens. A uniaxial load is applied through both the ends. The ASTM standard test method for tensile properties of fiber resin composites has the designation D 3039-76. Micro-hardness measurement is done using a Leitz micro-hardness tester. A diamond indenter, in the form of a right pyramid with a square base and an angle 136^0 between opposite faces, is forced into the material under a load F. The two diagonals X and Y of the indentation left on the surface of the material after removal of the load are measured and their arithmetic mean L is calculated. In the present study, the load considered F = 24.54N. Low velocity instrumented impact tests are carried out on composite specimens. The tests are done as per ASTM D 256 using an impact tester. The charpy impact testing machine has been used for measuring impact strength.

Figure 3.2 shows the tested specimens for impact test, hardness test and tensile test respectively. Figure 3.3 shows the experimental set up and loading arrangement for the specimens for three point bend test.

(a)

(b)

(c)

Figure 3.2 Tested specimens

Figure 3.3 Experimental set up and loading arrangement for the specimens for tensile test and three points bend test.

3.3. Scanning electron microscopy (SEM)

The scanning electron microscope (SEM) JEOL JSM-6480LV (Figure 3. 4) was used to identify the tensile fracture morphology of the composite samples. The surfaces of the composite specimens are examined directly by scanning electron microscope JEOL JSM-6480LV. The samples are washed, cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and observed SEM at 20 kV. Similarly the composite samples are mounted on stubs with silver paste. To enhance the conductivity of the samples, a thin film of platinum is vacuum-evaporated onto them before the photomicrographs are taken.

Figure 3.4 SEM Set up

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Chapter 4

MECHANICAL CHARACTERISTICS OF COMPOSITES: RESULTS & DISCUSSIONS

CHAPTER 4

MECHANICALCHRACTERISTICS OF COMPOSITES: RESULTS & DISCUSSIONS

This chapter presents the mechanical properties of the coir fiber reinforced epoxy composites prepared for this present investigation. Details of processing of these composites and the tests conducted on them have been described in the previous chapter. The results of various characterization tests are reported here. This includes evaluation of tensile strength, flexural strength, impact strength and micro-hardness has been studied and discussed. The interpretation of the results and the comparison among various composite samples are also presented.

4.1. Mechanical Characteristics of Composites

The characterization of the composites reveals that the fiber length is having significant effect on the mechanical properties of composites. The properties of the composites with different fiber lengths under this investigation are presented in Table 4.1.

Table 4.1 Mechanical properties of the composites

Composites	Hardness (Hv)	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)	Impact energy (KJ/m^2)
C_1	15	3.208	1.331	25.41	16.0
C_2	12.6	9.155	1.518	31.28	16.5
C_3	16.9	13.05	2.064	35.42	17.5

4.1.1. Effect of Fiber length on Micro-hardness

The measured hardness values of all the three composites are presented in Figure 4.1. It can be seen that the hardness is decreasing with the increase in fiber length up to 20mm. However further increase in fiber length increases the micro hardness value.

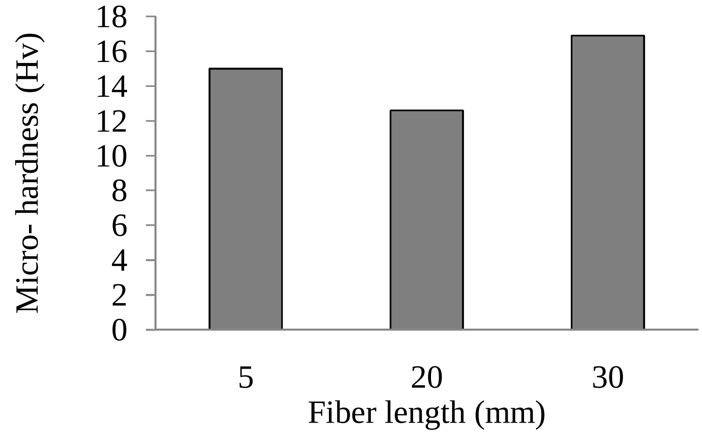


Figure 4.1 Effect of fiber length on micro-hardness of the composites

4.1.2. Effect of Fiber length on Tensile Properties

The test results for tensile strengths and moduli are shown in Figures 4.2 and 4.3, respectively. It is seen that the tensile strength of the composite increases with increase in fiber length. There can be two reasons for this increase in the strength properties of these composites compared. One possibility is that the chemical reaction at the interface between the filler particles and the matrix may be too strong to transfer the tensile. From Figure 4.3 it is clear that with the increase in fiber length the tensile moduli of the coir fiber reinforced epoxy composites increases gradually.

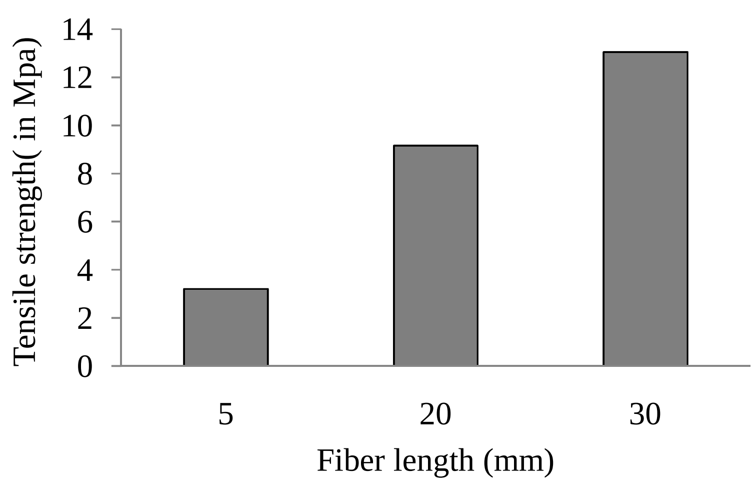


Figure 4.2 Effect of fiber length on tensile strength of composites

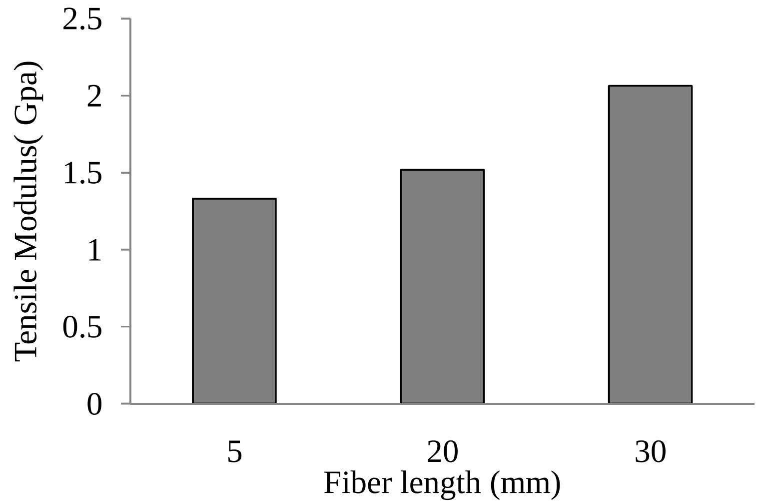


Figure 4.3 Effect of fiber length on tensile modulus of composites

4.1.3. Effect of Fiber length on Flexural Strength

Figure 4.4 shows the comparison of flexural strengths of the composites obtained experimentally from the bend tests. It is interesting to note that flexural strength increases with increase in fiber length.

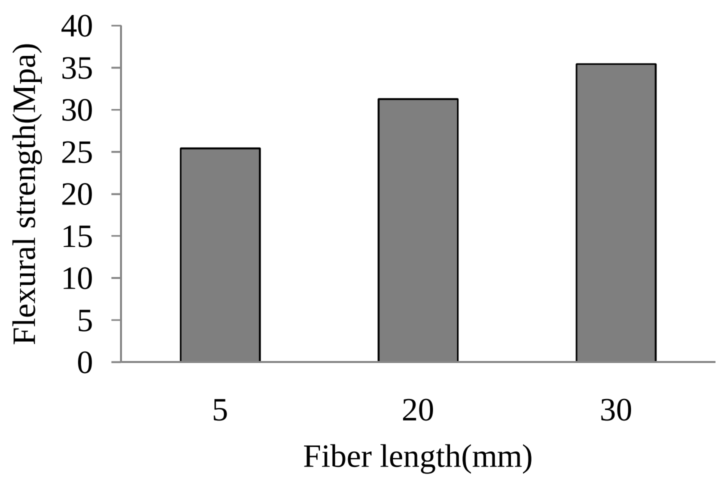


Figure 4.4 Effect of fiber length on flexural strength of composites

4.1.4. Effect of Fiber length on Impact Strength

The impact energy values of different composites recorded during the impact tests are given in Table 4.1. It shows that the resistance to impact loading of coconut coir fiber reinforced epoxy composites improves with increase in fiber length as shown in Figure 4.5. High strain rates or impact loads may be expected in many engineering applications of composite materials. The suitability of a composite for such applications should therefore be determined not only by usual design parameters, but by its impact or energy absorbing properties.

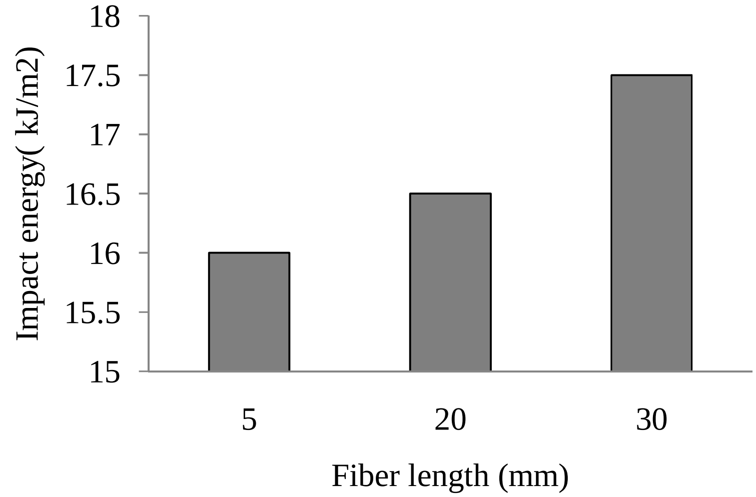
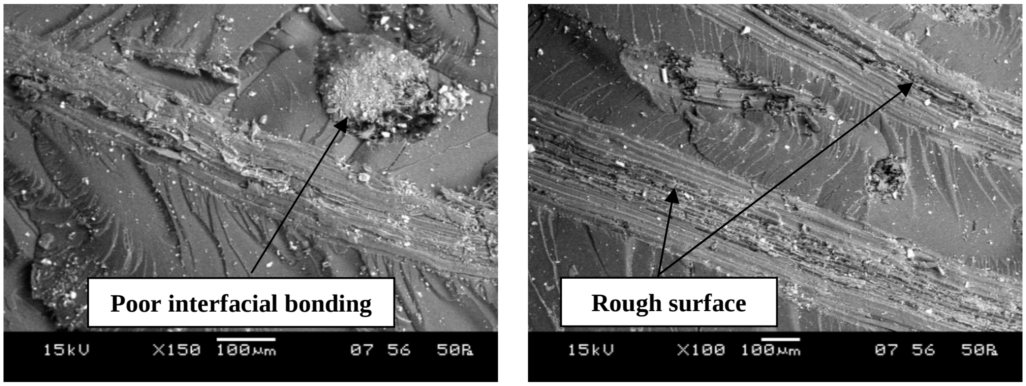


Figure 4.5 Effect of fiber length on impact strength of composites

4.2. Surface morphology of the composites

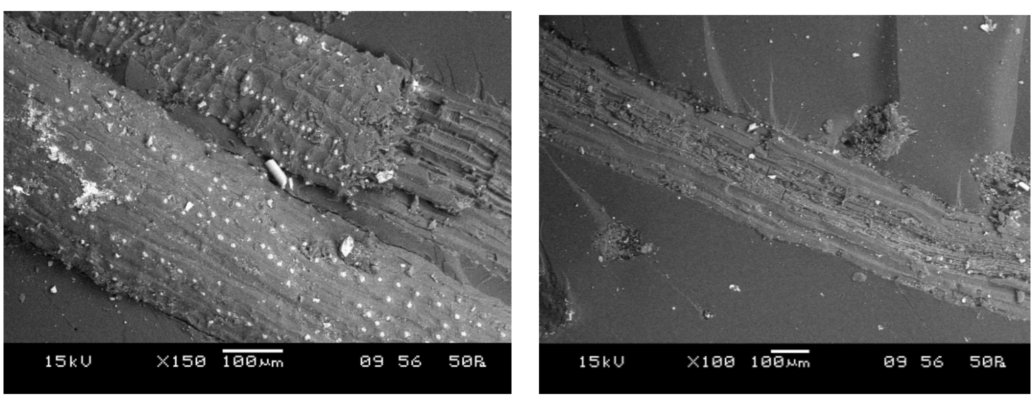
The fracture surfaces study of coir fiber reinforced epoxy composite after the tensile test, flexural test and impact test has been shown in Figures 4.6-4.8. SEM photograph of the cross section of the coconut coir fiber reinforced epoxy composite is shown in Figure. It shows the tensile fracture of coir/epoxy specimens. From Figure 4.6(a) it can be seen that the fibers are detached from the resin surface due to poor interfacial bonding. The surface of the fiber is not smooth indicating that the compatibility between fibers and epoxy matrices is poor. However this compatibility can be improve when fiber will be treated by chemical treatment methods (Figure 4.6(b)).



(a) (b)

Figure 4.6 Scanning electron micrographs of coir/epoxy specimens after tensile testing.

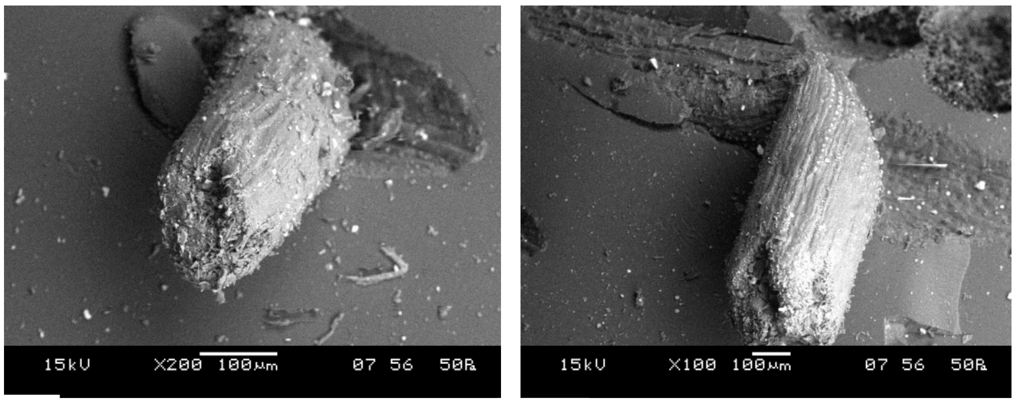
SEM photograph of the cross section of the coconut coir fiber reinforced epoxy composite is shown in Figure. It shows the coconut coir/epoxy specimen after flexural fracture. From Figure 4.7(a-b) it can be seen that the fibers are detached from the resin surface due to poor interfacial bonding. The presence of uneven fibers in a brittle resin in the coir/epoxy is probably the cause of the poor flexural strength [67].



(a) (b)

Figure 4.7 Scanning electron micrographs of coir/epoxy specimens after flexural testing.

SEM images of the impact fracture surface for coir fiber reinforced epoxy composite are shown in Figures 4.8. Pulled out fiber is clearly visible in the composite. In Figure 4.8 (a) it can be seen that the fiber has offered resistance and has absorbed energy in its own fracture. Furthermore, it can be seen that the surfaces of the pulled out fibers are clean. The lower impact strength of the coir/epoxy specimens was due to the poor interface bonding. Figure 4.8 (b) shows the fiber pull-outs are much longer and the fiber surfaces are cleaner which indicates an even worse adhesion between coconut coir fiber and epoxy resin.



(a) (b)

Figure 4.8 Scanning electron micrographs of coir/epoxy specimens after impact testing.

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Chapter 5

CONCLUSIONS

CHAPTER 6

CONCLUSIONS

This experimental investigation of mechanical behaviour of coconut coir reinforced epoxy composites leads to the following conclusions:

- This work shows that successful fabrication of a coir fiber reinforced epoxy composites with different fiber lengths is possible by simple hand lay-up technique.
- It has been noticed that the mechanical properties of the composites such as micro-hardness, tensile strength, flexural strength, impact strength etc. of the composites are also greatly influenced by the fibre lengths.
- The fracture surfaces study of coir fiber reinforced epoxy composite after the tensile test, flexural test and impact test has been done. From this study it has been concluded that the poor interfacial bonding is responsible for low mechanical properties.

5.1. Scope for Future Work

There is a very wide scope for future scholars to explore this area of research. This work can be further extended to study other aspects of such composites like effect of fiber content, fiber orientation, loading pattern, fiber treatment on mechanical behaviour of coconut coir based polymer composites and the resulting experimental findings can be similarly analyzed.

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